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PARAMETERS OF FUTURE ATC SYSTEMS RELATING TO AIRPORT CAPACITY/DELAY

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16. Abstract

The FAA, in conjunction with users of the major airports, is conducting a series of site specific case studies as to how to increase airport capacity--both now and in the future when the products of the FAA's Engineering and Development (E&D) program have been implemented as part of the operational ATC system. This document presents estimates of changes in longitudinal spacing on final approach that may be realized as the products of the E&D programs become available. It also discusses the potential for reducing interarrival errors and runway occupancy time. The parametric values presented are to be used by the FAA/User Group Airport Case Study Teams in assessing the potential impact of future airport/ATC changes on delay/capacity. Certain parameter values related to the estimation of present day delay/capacity are also presented.

This paper provides minor changes from FAA-EM-78-8, April 1978, "Parameters of Future ATC Systems Relating to Airport Capacity/Delay." It supersedes FAA-EM-78-8.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

A previous paper (Reference 1) developed a set of estimated longitudinal separation standards* and other parameters for use in studies relating to the assessment of future performance of the elements of the FAA Engineering and Development (E&D) program. This paper updates the previous study in order to provide current estimates to ongoing Airport Improvement Task Forces. It also provides guidance on use of capacity and delay models. This paper focuses on the performance characteristics of ATC systems only as they impact the choice of input values to capacity/delay modeling. No attempt is made to fully describe systems nor specify hardware system performance.

The values presented in this paper are based upon assumptions as to the performance characteristics of future ATC improvements stemming from the E&D program. In some cases, extensive development is required to demonstrate the achievability of the performance objectives. As a result, the estimates of the separation standards and other values may change as better estimates become available. Although some policy and operational constraints have been considered, these numbers do not constitute an operationally approved set of separation standards, but are representative of what may be expected in the future based on the current understanding of the E&D products. Hence, these estimates should be used only as guidance to the study of future ATC environments and not as a basis for present day airport decisions.

Two weather/ATC rules conditions need to be defined for the purpose of this paper. IFR weather is defined to imply a strict applicability of all IFR radar rules in limiting CAT I conditions. VFR weather represents a condition of visual approaches made while under positive control.

Section 2 provides a brief description of some E&D elements. Section 3 presents the capacity/delay model inputs. Section 4 addresses experimental designs for the Airport Improvement Task Forces, and Section 5 provides some notes on modeling technique.

Most of the material is addressed particularly to subgroups of the Airport Improvement Task Forces dealing with the design of experiments for the capacity/delay models and with preparation of data input to capacity/delay models. In some cases

*In this paper the terms "longitudinal separation standards" and "separation standards" refer to longitudinal separation standards on final approach (i.e., last 8-10 miles before touchdown).

(e.g., Section 5), further reference is made to the detailed structure and data requirements of the capacity/delay models. That section will be of interest to those who are concerned with more detailed information on modeling.

2. DEFINITION OF E&D ELEMENTS

Two of the current E&D programs are expected to have a major impact on airport capacity and delay. These are the Wake Vortex Advisory/Avoidance Systems (VAS/WVAS) and terminal area Metering and Spacing (M&S).

The Wake Vortex Advisory/Avoidance System is being developed to provide increased capacity by allowing for reduced aircraft separation standards under certain meteorological conditions. There are two levels of WVAS installations envisioned. The first level, called the Vortex Advisory System (VAS), consists of a system of wind sensors, located near the approach end of the runways, that transmit data to a central processing computer for assessment of hazardous vortex conditions. A display indicating predicted presence or absence of vortices in the approach corridor (referred to as red or green light conditions) will be provided to the controllers for use in the manual or computer-aided spacing of traffic. The second level, called the Wake Vortex Avoidance System (WVAS), is to be an advanced system utilizing vortex sensors and a more complex vortex behavior predictive algorithm to measure and predict vortex movement. The WVAS is to be designed to provide outputs that will allow for closer spacing between aircraft under certain conditions than will be possible with the less sophisticated VAS. Aircraft spacing data will be provided for automated integration into the M&S algorithms. The technical approach to be followed in achieving the WVAS objectives has yet to be selected.

The Metering and Spacing system is being developed to increase airport capacity by increasing the precision of the delivery of aircraft to the final approach course gate. This increase in precision will allow reduction in the extra spacing now used by the controller as the means of assuring that the required minimum aircraft separations are not violated. There are two levels of M&S performance: an initial (implementable) capability and a later, improved M&S capability. With the initial capability, interaircraft delivery accuracy at the start of the final approach is expected to be reduced from the approximately 18 seconds of today to 11 seconds (one standard deviation). It is anticipated that experience in the use of the initial M&S capability will lead to an improved M&S capability, with an increase in delivery accuracy to 8 seconds. Reduced error in delivery permits a greater number of aircraft to land.

There are several other future system improvements that may contribute to increasing airport capacity and reducing delay. The Discrete Address Beacon System (DABS) may be required to achieve

advanced M&S if it is found that automated delivery of M&S messages via the DABS data link will reduce the delivery error. The Airport Surface Traffic Control (ASTC) Systems may improve airport capacity under certain weather and airport configuration conditions. Similarly, the Microwave Landing System (MLS) may have capacity/delay benefits for specific configurations/ airspace geometries. These elements are not explicitly further considered in this paper. Brief descriptions of these E&D elements are contained in Reference 3.

Expected availability of reduced requirements for parallel IFR approaches is estimated.

While not an E&D element, runway occupancy time improvement is considered. This improvement may come about by construction and use of high speed exits, and better motivation for use of those existing exits which can be used to minimize runway occupancy time.

Other specific ATC system improvements may be applicable at individual airports and should be included in capacity/delay studies.

3. MODEL INPUT DEFINITION

Several inputs to capacity/delay models need to be defined. Several of these input values should be the same for any airport studied. As shown in Table 3-1, other model inputs are required to reflect airport specific operating conditions. Runway configuration uses, aircraft fleet mixes, and airspace restrictions should be airport specific. The following inputs are intended to be airport independent.

Arrival Separations

The first principle in developing arrival separations is that they should be structured as defined in ATC procedures (Reference 2), that is, as minimum separations which should not normally be violated.

Two weather/ATC rules conditions need to be defined uniformly for all airports. The first weather/ATC rules condition is a limiting CAT I IFR, in which all radar IFR separation rules are enforced, as per Reference 2. The minima today should be the 3, 4, 5, 4, 6 nmi (LL, HH, HL, LS, HS)* separations therein defined. These are minima which normally are not violated. The second weather/ATC rules condition is a VFR environment in which visual approaches are made while under positive control (e.g., TCA). Here the equivalent "minimum separations" (1.9, 2.7, 3.6, 2.7, 4.5 nmi) should be used.

These VFR minimum separations are not operational minima as consciously maintained by the controller, but rather reflect what field data shows under saturated conditions. They are used in the analysis to provide the best possible accuracy.

In the future VAS/WVAS should help provide for reduced spacing. Since Reference 1 was compiled, new estimates of VAS/WVAS performance have been developed. In the near term VAS is estimated to provide for IFR minimum separations that are all 3 nmi except for a heavy aircraft followed by a small aircraft, which may be 4 nmi. In the intermediate term, with WVAS, these should be reduced by 0.5 nmi for most aircraft pairs, as shown in Table 3-2. Finally in the far term, most separations are estimated to be reduced to 2 nmi.

*Here S, L, H refer to ATC weight classes of small, large, and heavy aircraft, respectively. Notation "HL" denotes a heavy aircraft followed by a large aircraft. The notation "LL" includes all pairings not otherwise denoted (i.e., SS, SL, SH, LL, LH).

TABLE 3-1

INPUTS FOR CAPACITY/DELAY MODELS

INPUTS WHICH SHOULD BE STANDARD FOR ALL AIRPORTS	INPUTS WHICH CAN BE SPECIFIC TO AN AIRPORT
ARRIVAL SEPARATIONS	ARRIVAL RUNWAY OCCUPANCY TIMES FOR TODAY
DEPARTURE SEPARATIONS	DEPARTURE RUNWAY OCCUPANCY TIMES
M&S SIGMA	AIRCRAFT FLEET MIX
M&S EXCEPTION RATE	AIRCRAFT VELOCITIES
IFR ARRIVAL RUNWAY OCCUPANCY TIME AND SIGMA IN THE FUTURE	COMMON APPROACH PATH
PARALLEL IFR OPERATIONS	RUNWAY CONFIGURATION, PROCEDURES AND PERCENT OF TIME USED
	AIRFIELD NETWORK, ROUTING AND VELOCITIES*
	AIRSPACE CONSTRAINTS*
	SCHEDULE/DEMAND*
	GATE ASSIGNMENTS AND SERVICE TIMES*

*FOR USE ONLY IN DELAY MODEL

TABLE 3-2

MINIMUM ARRIVAL SEPARATIONS

S = SMALL L = LARGE H = HEAVY

	IFR				VFR*		
TODAY							
TRAIL / LEAD	S	L	H	TRAIL / LEAD	S	L	H
S	3	3	3	S	1.9	1.9	1.9
L	4	3	3	L	2.7	1.9	1.9
H	6	5	4	H	4.5	3.6	2.7
NEAR TERM							
TRAIL / LEAD	S	L	H	TRAIL / LEAD	S	L	H
S	3	3	3	S	1.9	1.9	1.9
L	3	3	3	L	2.7	1.9	1.9
H	4	3	3	H	4	3	2.7
INTERMEDIATE TERM							
TRAIL / LEAD	S	L	H	TRAIL / LEAD	S	L	H
S	2.5	2.5	2.5	S	1.9	1.9	1.9
L	3	2.5	2.5	L	2.7	1.9	1.9
H	3.5	3	2.5	H	3.5	3	2.5
FAR TERM							
TRAIL / LEAD	S	L	H	TRAIL / LEAD	S	L	H
S	2	2	2	S	1.9	1.9	1.9
L	2.5	2	2	L	2.5	1.9	1.9
H	3	2.5	2	H	3	2.5	2

*THE 1.9, 2.7, 3.6, 4.5 NMI VFR MINIMUM SEPARATIONS SHOWN FOR TODAY ARE NOT OPERATIONAL MINIMA AS CONSCIOUSLY MAINTAINED BY THE CONTROLLER, BUT RATHER REFLECT WHAT FIELD DATA SHOWS UNDER SATURATED CONDITIONS. THEY ARE USED IN THE ANALYSIS TO PROVIDE THE BEST POSSIBLE ACCURACY.

In VFR conditions, the basic 1.9 nmi equivalent minimum separation would remain unchanged for all time frames. For other aircraft pairs, it is assumed that today's VFR separations will be reduced to match the improvement in IFR separations. These are also shown in Table 3-2.

The future dates associated with the time frames noted above can be qualitatively described as "pre-1985," "post-1985," and "near 1990." More specific determinations will need to be made by FAA Headquarters for each airport.

None of the envisioned vortex systems is expected to be able to provide for the reduced separations noted above under all weather/operating conditions. Under conditions of possible vortex hazard, it is anticipated that larger separations will be necessary. In varying steps, a future system could revert to any of the separations listed for previous time frames. Thus the far term IFR separations based on a minimum of 2 nmi could revert under adverse vortex conditions to any of three previous separation sets (intermediate term, near term, today). Rather than attempt a detailed, uncertain modeling of all these possible cases, only the separations for the desired future environment should be used, with the knowledge that the average benefit will be somewhat less than would be realized from full use of the lowest feasible separations. In most cases, it can be assumed that the benefit does reflect the most likely VAS/WVAS required separations.*

Departure Separations

Departure separations are shown in Table 3-3.

Minimum IFR departure separations, as specified in Reference 2, should be used. For today, heavy/heavy requires 90 seconds and heavy/nonheavy 120 seconds. All others can be spaced at 60 seconds. It is assumed an improvement will eventually be achieved to insure compatibility with arrival spacing reductions. The 60/90/120 values of today are assumed reduced to 60/60/90 in the intermediate term and 60/60/60 in the far term.

VFR separations in many cases are less than IFR separations. Future reductions shown in Table 3-3 are linked to IFR reductions.

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*Where a Task Force feels a need for a more explicit modeling, the assumption may be made that the future systems revert half the time to the next larger separation matrix (while retaining full performance of M&S, runway occupancy time reduction, and other E&D benefits).

TABLE 3-3

DEPARTURE SEPARATIONS

S = SMALL L = LARGE H = HEAVY

	IFR				VFR			
	LEAD \ TRAIL	S	L	H	LEAD \ TRAIL	S	L	H
TODAY	S	60	60	60	S	35	45	50
	L	60	60	60	L	50	60	60
	H	120	120	90	H	120	120	90
NEAR TERM	S	60	60	60	S	35	45	50
	L	60	60	60	L	50	60	60
	H	120	120	90	H	120	120	90
INTERMEDIATE TERM	S	60	60	60	S	35	45	50
	L	60	60	60	L	50	60	60
	H	90	90	60	H	90	90	60
FAR TERM	S	60	60	60	S	35	45	50
	L	60	60	60	L	50	60	60
	H	60	60	60	H	60	60	60

Metering and Spacing

Metering and spacing, and other relevant inputs, are reflected in Table 3-4.

The metering and spacing error of interest is the inter-aircraft delivery error of the system at the gate (i.e., where the metering and spacing function stops operating). For today's manual system an interarrival error (one sigma) of 18 seconds at the gate is consistent with most estimates. This may for modeling purposes be assumed to reflect error at threshold. The mean interarrival separation is assumed to be 1.65 sigma above the minimum separations noted above. For a normal distribution, this implies 5% of separations might be below the minimum separations. In fact, in most cases, the controller acts to prevent these cases from occurring. It does, however, provide a measure of the relationship between the mean and minimum separation.

Under the intial (implementable) M&S system in the near term the interarrival error is assumed reduced to 11 seconds. In the far term, the M&S capability is assumed to improve to where the error is reduced to 8 seconds. For all future cases, the decreased flexibility provided by a semi-automated system (vs. today's manual system) is assumed to change the relationship between the mean and minimum separations. In these future time frames the mean shall be estimated as 2.33 sigma above the minimum to account for the loss of the human flexibility in today's system to resolve potential spacing conflicts. Assuming a normal distribution, this would leave only 1% exceptions below the minimum specified spacing.

Runway Occupancy Time

In many airports, with reduced spacing, runway occupancy time can constrain the operation of the airport. Even with today's exit placement, an improvement in runway occupancy time in the future is probable. An airport specific analysis stressing the use of available versus commonly used exits may be necessary. For most runways at major airports, reductions of runway occupancy times (mean) to 42, 50, 53 seconds for small, large, heavy aircraft in IFR seem feasible with pilot cooperation in the use of the first feasible exit, and should be assumed for an intermediate period. The values for VFR should be 5-10 seconds lower (depending on local airport conditions). In the far term, installation of additional high speed exits (as necessary) should reduce these values to at least 34, 42, 45 seconds (mean). Values for VFR may be up to 5 seconds lower.

TABLE 3-4

OTHER INPUT PARAMETERS

	M&S SIGMA (SEC)	M&S EXCEPTION RATE (%)	IFR RUNWAY OCCUPANCY TIME		IFR PARALLEL RUNWAY SPACING	
			MEAN (SEC)(1)	SIGMA (SEC)	SIMULTANEOUS (FEET)	DEPENDENT (FEET)
TODAY	18	5	AIRPORT SPECIFIC	8	4300	3000(2)
NEAR TERM	11	1	AIRPORT SPECIFIC	8	4300	3000
INTERMEDIATE TERM	11	1	42,50,53	6	3000	2500
FAR TERM	8	1	34,42,45	4	2500	2500

(1) IN FORM SMALL, LARGE, HEAVY. VFR VALUES MAY BE LESS, AND MAY BE AIRPORT SPECIFIC.

(2) AS OF 1 JULY 1978.

There may be an improvement in the variability of occupancy times. One sigma values of 7-12 seconds are commonly observed today. On runways with consistent exiting patterns the sigma is around 8 seconds. In the two stages this may improve to 6 and 4 seconds, respectively.

It should be noted that runway occupancy time improvement is necessary to realize the full benefit from an E&D program. Such improvement can be, however, achieved separately from other E&D element implementation.

Parallel Runways

Under IFR conditions, current procedures require 4300 foot runway spacing for simultaneous approaches. With the addition of a precision surveillance system, this could be reduced to 3000 feet. In the far future, a 2500 foot separation may be possible.

There may be potential for dependent parallel operations, for instance, with a 2 nmi separation between arrivals on alternate runway approaches. This was done in Atlanta prior to the current 4300 foot rule for simultaneous parallel operations. This would present less demanding requirements and could find earlier implementation than fully simultaneous approaches. In conjunction with this, there may be lessened requirements for runway spacing for independent arrival and departure operations. Determination of applicability would have to be made by FAA Headquarters for each airport.

Procedure for Changes

The above should serve as guidance for model inputs. However, at some airports local operating conditions may dictate some modifications. Potential changes should first be substantiated by careful analysis of field data and control procedures. Some comments on this process are found in Appendix A.

4. EXPERIMENTAL DESIGNS

The inputs developed in this paper were primarily designed for use with the Airport Improvement Task Forces. Several aspects of the experimental design for use of capacity/delay models at the Task Forces are presented in this section. While this guidance is specifically developed for Task Forces, it should be of interest as well for other applications of the material in this paper.

Model Inputs

In the current Airport Improvement Task Forces there are several objectives apart from evaluation of the impacts of E&D elements. The major use of capacity/delay models is to evaluate the impact of near term improvements of varied nature. However, in order to provide an orderly set of comparisons, the values presented in this paper (including those for today) should be used when evaluating impacts of all improvements, not just those associated with FAA E&D products.

In some cases, Task Forces may feel that input values more specific to an individual airport should be used in some model runs. This issue is further addressed in Appendix A.

Quality of Approximation

The concept introduced above necessarily removes some of the airport specific nature of model inputs. The inputs described should not materially degrade the value of model outputs. They are structured to recognize critical airport specific realities, yet retain an important basis for inter-airport comparison. Output values in all cases should represent a conservative picture of the airport's capability.

Aircraft Classes

To maintain reasonable consistency, aircraft speed classes may be defined in the following manner. Four aircraft classes may be defined in the capacity/delay models currently employed. One each should be small, large and heavy. The remaining class should be small or large, depending on airport specific conditions with respect to

- fleet mix and growth,

- speed profiles.

Other Weather/ATC Rules Conditions

All previous Task Forces have employed the two weather/rules conditions defined in Section 3. Most Task Forces have also defined additional weather/rules conditions, such as

- a more restricted VFR without visual approaches,
- a marginal (e.g., 800/2) IFR,
- a CAT II IFR.

Flexibility to permit these additional definitions should continue while retaining the IFR, VFR conditions defined in this paper as the primary representations of airport operations. There are several ways of dealing with these additional environments without conflict to the modeling structure defined above:

- relax or tighten other ATC rules (e.g., visual approaches, independence of runways),
- interpolate between capacity/delay values for other weather/rules conditions,
- modify input separations, attempting to maintain consistency with IFR, VFR cases above. This process would require the most computer and personnel resources and a considerable speculation to derive suitable inputs; it is not recommended.

The first method above is easily implemented in most cases. For example, "restricted VFR" conditions occur most often when independent close parallel approaches can no longer be flown as part of visual approaches. This can be readily modeled. Similarly, marginal IFR (above 800/2) can be reflected by relaxation (within the normal model logic) of the 2 nmi departure/arrival constraint. Basic VFR/IFR separation matrices, as presented in this report, should be retained thoughout this process.

5. MODELING ISSUES

Several issues arise when the inputs of Section 3 are applied to the operation of a specific capacity or delay model. In some cases the model may operate somewhat differently than a modeler might imply from the listing of inputs. Here the modeler must provide additional insights to insure the model run actually fits his needs. This section presents some of these issues that relate to the models provided by Peat, Marwick, Mitchell and Co., and specified by the FAA for use in the Airport Improvement Task Forces:*

- airfield capacity model,
- annual delay model,
- airfield delay simulation model.

The observations may be useful, as well, in employing other capacity and delay models.

The relationship between the mean and minimum arrival separations can be stated:

$$\text{minimum}_{I.A.T.} + N * \sigma_{I.A.T.} = \mu_{I.A.T.}$$

where:

$\text{minimum}_{I.A.T.}$	=	minimum interarrival time at point of closest approach.
$\mu_{I.A.T.}$	=	mean interarrival time at point of closest approach.
$\sigma_{I.A.T.}$	=	sigma (standard deviation) of inter-arrival time (18, 11, 8 seconds).
N	=	number of standard deviations in I.A.T. (M&S) buffer. This is given as 1.65 (5%) today and 2.33 (1%) in future M&S environments (assuming normality).

*Documentation of capacity/delay models provided by Peat, Marwick, Mitchell & Co. of FAA for use at Airport Improvement Task Forces is available from FAA's Office of Systems Engineering Management, Systems Engineering Division.

In order to preserve this structure without disturbing other model inputs, mean separations (for each aircraft class pair) must be calculated in the above manner from minima of Table 3-2 and then converted to appropriate model inputs. If not done in this manner, other buffers, which should not be affected by the M&S change, would be increased. (Details of this model input procedure for the capacity model are presented in Appendix B.) Other related items in the model can then remain undisturbed by this process:

- buffer (exception rate) for all operations (5%),

- sigmas for arrival, departure occupancy, and departure clearance. The sigma value for interarrival delivery (18, 11 or 8 seconds) is entered in the usual manner.

The mean standard deviation for runway occupancy need to be modified for use in the airfield delay model. The required input form for runway occupancy time is as times and probabilities for use of each exit of each runway.

The models, as noted previously, should be used with respect to the full benefit of reduced spacings for each future environment. The expected benefit level is lower, since the VAS/WVAS revert to higher spacings during some portion of the time. The benefit should always be between the measured value and the value for the previous time frame. It is moved downward by the higher standards some portion of the time and the increasingly heavy aircraft fleet mix. It is moved upward because most of the time the reduced standards may be usable, and because improvements in M&S and runway occupancy remain even when separations revert to higher values.

In all capacity runs for future time frames (at 50% arrivals) care needs to be exercised to determine a capacity based on the most efficient use of the airfield configuration. This requires full knowledge of the model. One improvement in model performance has been to calculate capacity as the maximum of:

- the value given by the capacity model as usually employed, (arrival priority) and

- the value given by the model option requiring one departure to be interleaved between each arrival pair, for all mixed operations configurations (equal priority).

This comparison should be performed for all capacity runs, where possible.

Finally, the user needs to be vigilant to check the reasonableness of results. The models have been primarily designed to measure the current airport environment. When future environments are modeled, especial care is required to determine how best to use the model to estimate capacity.

APPENDIX A

MODIFICATIONS TO RECOMMENDED MODEL INPUTS

Much data needs to be assembled to adequately run capacity/delay models. This is particularly true of the airfield simulation model. There is a tendency to want to accept in detail any and all data coming out of field data collections. This may conflict with the methodology presented in this paper. Some observations on this process are presented in this appendix.

Use of Field Data

Field data, per se, may not present an appropriate set of inputs for any model. First, the data may not be accurate:

- Small sample sizes may mean there is unstable data

- The field data collection conditions may not have reflected the assumed typical operations

- Observed demand may be well less than saturation.

It may also be that the field data, directly input to the model, may cause inappropriate results, even in today's environment. This is particularly true of arrival separations. For example (with respect to the capacity model):

- If the arrival separations in the field (and input to the model) were actually constrained by "large" runway occupancy times, then the model will be incapable of showing a benefit from a reduction in runway occupancy time. The model "sees" the separations as irreducible, so lower runway occupancy times may be input but have no effect on the output.

- If the arrival separations in the field (and input to the model) were actually constrained by interaction with departures, then the model would be incapable of providing an evaluation of changes in procedures for departures.

Modified Model Input

In light of the above discussion, and the rationale expressed in the body of the paper, the set of inputs in Tables 3-2 though 3-4 should be used throughout. At the very least, they should be used in any and all model experiments that relate to the evaluation of E&D products.

In the event a Task Force or other party still feels some field data should be used, the following guidelines must be retained if credibility of overall results is to be achieved.

1. Any potential changes from the inputs of Section 3 should first be substantiated by careful analysis of field data and control procedures.

2. IFR minimum arrival separations should remain at 3, 4, 5, 6 values specified by Reference 2. Lower values would imply a disregard for required ATC procedures. In the capacity phase of the first seven Task Forces, some of the "mean separations" used for baseline runs may have variances from the guidance. However, these variances, which were based on the field data available at the time, did not have a significant impact on the overall conclusions. For future time frames, the values in Table 3-2 should hold. The same rationale should apply to IFR departure separations.

3. VFR equivalent minimum arrival separations should be no larger than the minimum of field observed VFR separations and the corresponding IFR minimum separations for the particular time frames. The same rationale should apply to VFR departure separations.

4. Increases in IFR, VFR separation values for today above the levels of Section 3 should be made only when specific constraints are identified (e.g., airspace congestion). Future values then would need to be identified on a case-by-case basis depending on the governing constraint.

APPENDIX B

AIRCRAFT SEPARATIONS FOR MODEL INPUT

The basic structure defined in Section 5 for the development of model inputs for aircraft separations is further explained here. The definitions are as they are used in the current version of the capacity model.

Let: SS_{ij} = minimum separation standard defined in Table 3-1, for lead aircraft class i and trail aircraft class j (nmi)

V_j = velocity of trail aircraft class j (knots)

σ = interarrival standard deviation (seconds)

Z_{ED} = number of standard deviations in buffer for E&D purposes. This will be 1.65 (5%) or 2.33 (1%) depending on the future time frame.

Z_{PMM} = number of standard deviations in buffers as used throughout in PMM&Co. use of capacity model. This is to be 1.65 (5%)

DV_{ij} = factor to account for opening between lead aircraft class i and trail aircraft class j (since this eventually cancels out for purposes of this Appendix, it is not further defined)

$AASR_{ij}$ = mean arrival separation at threshold for lead aircraft class i and trail aircraft class j (sec)

δ_{ij} = minimum arrival separation at point of closest approach for lead aircraft class i and trail aircraft j (as used for model input) (nmi)

Then,

$$AASR_{ij} = 3600 * SS_{ij}/V_j + \sigma * Z_{ED} + DV_{ij}$$

The model requires as input δ_{ij}, and

$$\delta_{ij} = (AASR_{ij} - DV_{ij} - \sigma * Z_{PMM}) * V_j/3600$$

$$= V_j/3600\ [3600 * SS_{ij}/V_j + \sigma * Z_{ED}$$

$$+ DV_{ij} - DV_{ij} - \sigma * Z_{PMM}]$$

$$= V_j/3600\ [3600 * SS_{ij}/V_j + \sigma * (Z_{ED} - Z_{PMM})]$$

And thus

$$\delta_{ij} = SS_{ij} + V_j * \sigma/3600 * (Z_{ED} - Z_{PMM})$$

Thus, given SS_{ij}, the δ_{ij} for model input are calculated by the above expression. This can be done by hand, or a small utility program can be used.

It should be noted that for the current ATC environment Z_{ED} will equal Z_{PMM}, and no model input adjustments are necessary.

Similar processes must be used for the airfield delay model. In that model, however, the required input is mean separation at the point of closest approach, that is

$$\mu_{ij} = SS_{ij} + \sigma * Z_{ED}$$

APPENDIX C

REFERENCES

1. Sinha, A. N. and Haines, A. L., "Longitudinal Separation Standards on Final Approach for Future ATC Environments." MITRE Metrek, MTR-6979, October 1975.

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